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THE EFFECT OF PUNISHMENT ON FREE-OPERANT CHOICE BEHAVIOR IN HUMANS

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During Phase I, three female human subjects pressed a button for monetary reinforcement in five variable-interval schedules specifying different frequencies of reinforcement. On alternate days, responding was also punished (by subtracting money) according to a variable-ratio 34 schedule. In the absence of punishment, response rates conformed to Herrnstein's equation for single variable-interval schedules. Punishment suppressed responding at all frequencies of reinforcement. This was reflected in a change in the values of both constants in Herrnstein's equation: the value of the theoretical maximum response-rate parameter was reduced, and the parameter describing the reinforcement frequency corresponding to the half-maximal response rate was elevated. During Phase II, the same five schedules (A) were in operation (without punishment), but in addition, a concurrent variable-interval schedule (B) of standard reinforcement frequency was introduced. On alternate days, responding in Component B was punished according to a variable-ratio 34 schedule. In the absence of punishment, absolute response rates conformed to equations proposed by Herrnstein to describe performance in concurrent schedules; the ratios of the response rates in the two components and the ratios of the times spent in the two components conformed to the Matching Law. When responding in Component B was punished, response rates in Component B were reduced and those in Component A were elevated, these changes being reflected in distortions of the matching relationship.

Key words: Herrnstein's equation, matching law, response rates, reinforcement frequency, variable interval, variable-ratio punishment, concurrent schedules, button pressing, humans

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Herrnstein (1970) proposed an equation of the following form to describe the relationship between response rate (R) and reinforcement frequency (r) in variable-interval (VI) schedules of reinforcement:

$$R = R_{max} \cdot r/(K_H + r), \qquad (1)$$

where R_{max} and K_H are constants expressing the theoretical maximum response rate, and the reinforcement frequency corresponding to the half-maximal response rate, respectively (Herrnstein, 1974; Bradshaw, Szabadi, and Bevan, 1976).[2] This equation has been shown to describe accurately the behavior of pigeons, rats (for review, see de Villiers and Herrnstein, 1976; de Villiers, 1977), and humans (Bradshaw *et al.*, 1976, 1977, 1978) responding under VI schedules.

If an organism is exposed to a concurrent schedule consisting of two VI components, A and B, the response rates in the two components can be described by the following equations (Herrnstein, 1970):

$$R_A = R_{max} \cdot r_A/(K_H + r_A + r_B) \qquad (2)$$

$$R_B = R_{max} \cdot r_B/(K_H + r_A + r_B), \qquad (3)$$

if the value of r_B is held constant, it follows from Equation 2 that R_A will increase with increasing values of r_A, whereas it follows from Equation 3 that R_B will decline with increas-

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[2]Some controversy surrounds the theoretical interpretation of K_H. Herrnstein (1970, 1974), who uses the expression r_o, assumes that it reflects the frequency of "extraneous" reinforcement; on the other hand Catania (1973), who uses the expression C, has suggested that it reflects the hypothetical inhibitory effects of reinforcement. These, and other rival formulations have been reviewed by Staddon (1977). Since the empirical validity of Equation 1 is independent of these various interpretations, the neutral expression K_H has been adopted here (see also Bradshaw, 1977).

ing values of r_A. The empirical validity of Equations 2 and 3 has been confirmed both in the case of pigeons (Catania 1963; Davison and Hunter, 1976; Lobb and Davison, 1975) and humans (Bradshaw *et al.*, 1976). If it is assumed that the values of R_{max} and K_H are invariant between the two component schedules, Equations 2 and 3 may be combined to yield the "Matching Law" (Herrnstein, 1970):

$$R_A/(R_A + R_B) = r_A/(r_A + r_B) \quad (4a)$$

or

$$R_A/R_B = r_A/r_B. \quad (4b)$$

The Matching Law has been extensively supported by experimental observations both with animals and with humans (for review, see de Villiers 1977).

Comparison of Equations 1 and 2 enables a prediction to be made about the effects of introducing an additional schedule of reinforcement. Since both equations define a rectangular hyperbola that approaches an asymptote R_{max}, the introduction of a concurrent source of reinforcement should not alter the theoretical maximum response rate, although it should increase the reinforcement frequency needed to obtain the half-maximal response rate:

from Equation 1

$$R = R_{max}/2 \text{ when } r = K_H \quad (5)$$

from Equation 2

$$R_A = R_{max}/2 \text{ when } r_A = K_H + r_B. \quad (6)$$

Results consistent with this prediction have been obtained using humans as subjects (Bradshaw *et al.*, 1976), although experiments with pigeons (Davison and Hunter, 1976) have yielded equivocal results.

In a previous study (Bradshaw *et al.*, 1977), we found that punishment, in the form of response cost delivered on a variable-ratio (VR) schedule, produced a marked suppression of the responding of humans in single VI schedules. This suppression was reflected in a change in the values of both constants in Equation 1: the value of R_{max} was reduced and that of K_H was elevated. In the present experiment, we extended these observations by examining the effects of VR punishment on performance in concurrent as well as single VI schedules. The aim of the experiment was to determine how the superimposition of a VR punishment schedule on one component of a two-component concurrent schedule would affect the quantitative relationships defined by Equations 2 to 6.

METHOD

Subjects

Three female subjects, B.B. (39 yr), L.K. (53 yr), and M.S. (54 yr), were recruited by advertisement from the domestic staff of the University of Manchester. All were experimentally naive at the start of training and had had no previous instruction in psychology.

Apparatus

Experimental sessions took place in a small room. The apparatus used is illustrated in Figure 1. The subject sat at a desk facing a sloping panel 40 cm wide and 30 cm in height. Mounted on the panel were three rows of indicator lamps, the upper row amber, the middle row blue, and the lower row white; the lamps in each row were numbered 1 to 5, from left to right. Below the row of white lamps was a digital counter, beneath which were mounted two additional lamps, one green and one red. In front of the panel was a button that could be depressed by a force of approximately 6 N. Auditory response feedback was provided by a relay situated behind the panel.

During Phase II, (see below, Procedure), a small auxiliary box was also present on the desk. Mounted on this box were three lamps (from left to right: amber, blue, and white) and a button that could be depressed by a force of approximately 2 N.

Conventional electromechanical programming and recording equipment was situated in another room judged by the experimenters to be out of earshot from the experimental room.

Procedure

The procedure for the entire experiment is summarized in Table 1. The experiment consisted of two phases.

Phase I. On the first day of training, the subjects were instructed as follows:

> This is a situation in which you earn money. You earn money simply by pressing this button. Sometimes when you press the button the green light will flash on:

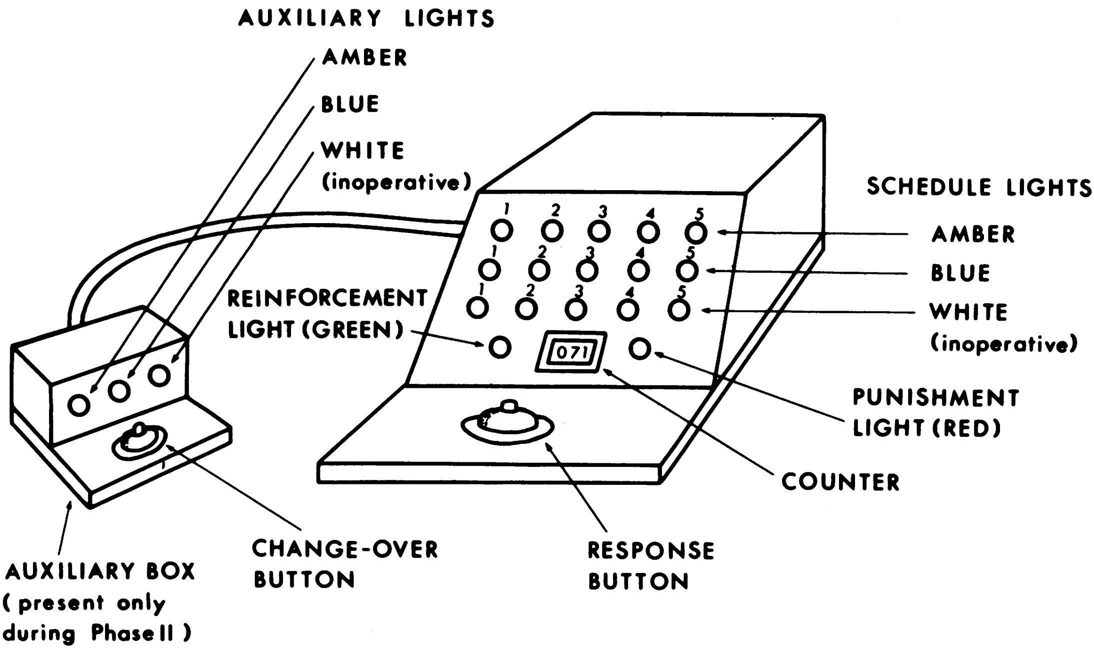

Fig. 1. Diagram of apparatus.

this means you will have earned one penny. The total amount of money you have earned is shown on this counter. You will start each day with 25p registered on the counter; every time the green light flashes it adds one point to the total score. (Please ignore the red light; it will not apply to you for the first two days.) When operating the button, make sure you press hard enough. You can tell whether you have pressed hard enough by listening for a slight click coming from inside the box. Now look at these amber lights (you don't have to worry about the blue and white lights). When one of the amber lights is on, it means that you are able to earn money. At the beginning of the session one of the lights will come on and will stay on for 10 minutes, and throughout this time you may earn money. At the end of 10 minutes the light will go off for 5 minutes, and during this time you should rest. After the rest period, another light will come on, again for 10 minutes, and you may earn some more money. Then there will be another rest

Table 1

Summary of Procedure

		Component A: Schedule	Component A: Schedule Lights	Component B: Schedule	Component B: Schedule Lights
PHASE I					
(30 sessions)	a.	VIs 1-5* no punishment	amber	—	—
alternate sessions	b.	VIs 1-5 with VR 34 punishment	blue	—	—
PHASE II					
(20 sessions)	a.	VIs 1-5 no punishment	amber	VI (standard) no punishment	amber
alternate sessions	b.	VIs 1-5 no punishment	amber	VI (standard) with VR 34 punishment	blue

*See text for details of individual VI schedules.

period, and so on, until each of the five-amber lights has been presented. At the end of the session we will take the reading from the counter and note down how much you have earned. You will be paid in a lump sum at the end of the experiment.

The five amber lights were each associated with a different VI schedule. Constant probability schedules were used, as described by Catania and Reynolds (1968). The reinforcement frequencies specified by the schedules were as follows: 1: 445 reinforcements per hour (VI 8-sec); 2: 211 reinforcements per hour (VI 17-sec); 3: 70 reinforcements per hour (VI 51-sec); 4: 21 reinforcements per hour (VI 171-sec); 5: five reinforcements per hour (VI 720-sec). Reinforcement consisted of a 100-msec illumination of the green light and the addition of one point to the score displayed on the counter. The VI programmer stopped during reinforcement delivery.

On the third day, the subjects received the following additional instructions:

The last two days were "amber-light days". Today and every alternate day until further notice will be a "blue light day". On "blue-light days" you will not only stand a chance of winning money, but also of losing money. Sometimes when you press the button the red light will flash and one penny will be subtracted from your total score displayed on the counter. As usual, "wins" will be signalled by the green light. Incidentally, you can completely ignore the white lights, because they will never apply to you in this experiment.

On "blue-light days", punishment, consisting of a 100-sec illumination of the red light and the subtraction of one point from the score displayed on the counter, was delivered according to a VR 34 schedule, irrespective of which VI schedule was in operation. The distribution of the ratios in the VR punishment schedule was the same as the distribution of the intervals in the VI reinforcement schedule. If a reinforcement and a punishment were both scheduled for the same response, both the green light and the red light were illuminated, but the score displayed on the counter did not change.

The five VI schedules were presented in a random sequence, with the constraint that each schedule occurred in a different ordinal position on successive days. Long schedule presentations (10 min) and interposed 5-min timeout periods were used to minimize behavioral interaction between the individual schedules (see Bradshaw *et al.*, 1976). Phase I continued for 30 successive working days.

Phase II. During Phase II, the auxiliary box was present on the subject's desk. On the first day of Phase II, the subjects received the following instructions:

From today onwards there will be a slight change in the situation. Every day from now on will be an "amber-light day". However, in addition to the main box, you can see that we have introduced this small extra box. Whenever one of the amber lights on the main box is on, you may, whenever you wish, change over to one of the lights on the extra box. You change over simply by pressing this button on the extra box: this turns the light on the main box *off*, and at the same time turns the light on the extra box *on*. In order to go back to the light on the main box, you just press the button on the extra box a second time. The button on the extra box is only for changing over; the button on the main box is the one you press in order to obtain money. Today and on every alternate day from now on, you will be able to change over to the extra amber light. On the intervening days you will be changing over to the extra blue light. You can ignore the white light on the extra box: it will not apply to you at all in this experiment.

During Phase II, the five amber lights on the main box were associated with the same VI schedules as during Phase I. The amber light on the auxiliary box was associated with a standard VI schedule, identical to that associated with amber light 3 on the main box (VI 171-sec; 70 reinforcements per hour). The blue light on the auxiliary box was associated with an identical VI schedule, upon which was superimposed a VR 34 punishment schedule (*i.e.*, a schedule identical to that associated with blue light 3 during Phase I). No restriction was imposed on the frequency with which subjects could change over from one component to another, and no changeover delay was employed. Phase II continued for 20 successive working days.

RESULTS

Phase I

a. Performance in the absence of punishment. The mean response rates (R ± s.e.m.) recorded in each schedule during the last three "amber-light days" (no punishment) were calculated individually for each subject and were plotted against delivered reinforcement frequency (r). Rectangular hyperbolae were fitted to the data by nonlinear regression analysis (Wilkinson, 1961). The data obtained from all three subjects are shown in Figure 2 (filled circles). The estimated values (±s.e. est.) of the theoretical maximum response rate and the reinforcement frequency corresponding to the half-maximal response rate obtained from the nonlinear regression analyses are shown in Table 2. The index of determination (p^2) was calculated from the curve obtained from each subject [p^2 expresses the proportion of the variance in the y-values that can be accounted for in terms of x in a curvilinear function (Lewis, 1960; see also Bradshaw *et al.*, 1976, 1977)]. The values of p^2 were 0.879 (B.B.), 0.878 (L.K.), and 0.983 (M.S.)

b. Performance in the presence of punishment. For each subject, the mean response rates (R ± s.e.m.) recorded in each schedule during the last three "blue-light days" (with VR 34 punishment) are shown in Figure 2 (open circles), and the estimated values of the constants are shown in Table 2. The values of p^2 were 0.954 (B.B.), 0.998 (L.K.), and 0.992 (M.S.).

All three subjects showed a marked suppression of responding in the presence of punishment on all five VI schedules. In the case of each subject, this suppression was reflected in a statistically significant decrease in the value of the theoretical maximum response rate, and in a statistically significant increase in the value of the reinforcement frequency corresponding to the half-maximal response rate.

Phase II

a. Performance in the absence of punishment. The results obtained from each subject during the last three sessions without punishment are shown in Figure 3 (filled symbols and

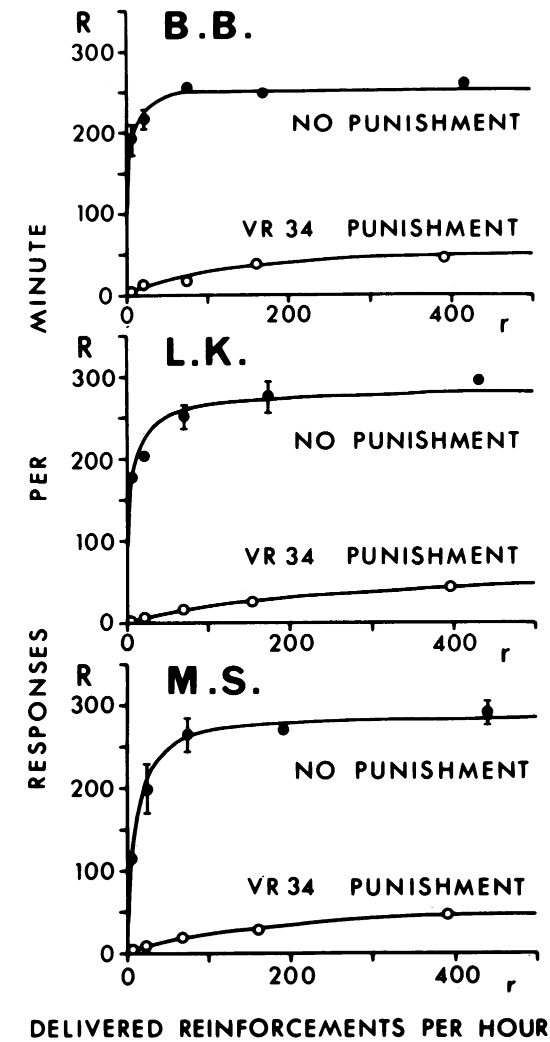

Fig. 2. Results obtained during Phase I. Relationship between response rate (R) and reinforcement frequency (r) in variable-interval schedules of monetary reinforcement for three subjects. Points are mean response rates (± s.e.m.) for last three sessions in the absence of punishment (filled circles) and in the presence of variable-ratio 34 punishment (open circles). Curves are best-fit rectangular hyperbolae, fitted by nonlinear regression analysis. (Note that the values of r refer to frequencies of delivery of positive reinforcement; punishment frequency has not been subtracted.)

continuous curves), and the values of the constants are shown in Table 2.

For each subject, the rate of responding in Component A (R_A) was an increasing, negatively accelerated function of reinforcement frequency in Component A (r_A). Compared to the values of the constants obtained during Phase I (no punishment), there was, for each subject, a statistically significant increase in

Table 2

Estimated values of the constants, obtained by nonlinear regression analysis from plots of response rate *versus* delivered reinforcement frequency (see Figures 2 and 3).

	Maximum Response Rate (±s.e.est.) in Component 'A' (resp/min)				*Reinforcement Frequency Needed to Obtain Half-Maximal Response Rate (±s.e.est.) in Component 'A' (reinf/hr)*			
	Phase I		*Phase II (Component 'B' Present)*		*Phase I*		*Phase II (Component 'B' Present)*	
Subject	*No Punishment*	*VR 34 Punishment*	*No Punishment*	*VR 34 Punishment in Component 'B'*	*No Punishment*	*VR 34 Punishment*	*No Punishment*	*VR 34 Punishment in Component 'B'*
B.B.	251.1 (± 7.0)	73.3 (±15.2)***	294.6 (±34.4)	263.5 (± 9.0)	1.9 (±0.5)	185.5 (±97.8)*	74.0 (±28.9)**	5.2 (±1.1)*
L.K.	275.0 (±17.5)	73.5 (± 4.5)***	296.1 (±18.4)	266.3 (± 7.9)	3.6 (±1.6)	272.0 (±32.3)***	30.4 (± 7.9)**	3.5 (±0.8)
M.S.	291.6 (± 7.9)	79.8 (± 9.6)***	350.6 (±52.8)	264.5 (±20.2)	8.6 (±1.3)	254.7 (±62.6)***	91.6 (±45.9)*	4.7 (±2.3)

Significance of changes in the values of the constants compared to the values obtained during Phase I (no punishment): normal distribution, *** $p<0.0001$, ** $p<0.01$, * $p<0.05$.

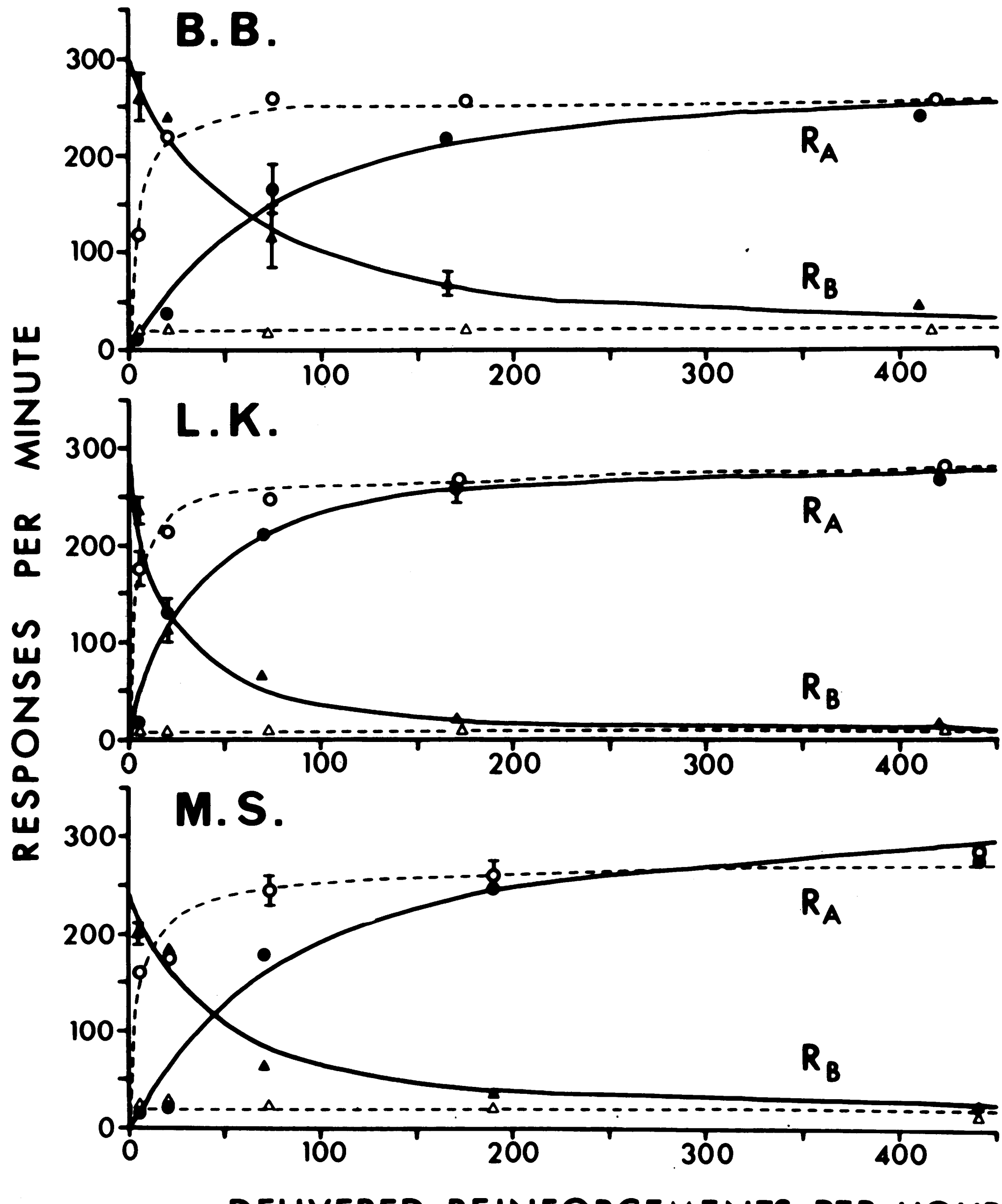

Fig. 3. Results obtained during Phase II. Absolute response rates in Component A (R_A, circles) and Component B (R_B, triangles) plotted against reinforcement frequency in Component A (r_A). Points are mean response rates (± s.e.m.) for last three sessions in the absence of punishment (closed symbols) and in the presence of variable-ratio 34 punishment for responding in Component B (open symbols). Curves were fitted by nonlinear regression analysis.

the value of the reinforcement frequency corresponding to the half-maximal response rate; however, the value of the theoretical maximal response rate was not significantly altered. The values of p^2 for the hyperbolic functions were 0.972 (B.B.), 0.983 (L.K.), and 0.954 (M.S.).

For each subject, the rate of responding in Component B (R_B) decreased asymptotically with increasing values of r_A. Curves having the form defined by Equation 3 were fitted to the data by the method of Wilkinson (1961). The values of p^2 for these functions were 0.975 (B.B.), 0.981 (L.K.), and 0.946 (M.S.).

The ratios of the response rates in the two components (R_A/R_B) were plotted against the ratios of the reinforcement frequencies in the two components (r_A/r_B), using double logarithmic coordinates (Baum 1974). Best-fit linear functions were fitted to the data using the method of least squares. The results obtained are shown in the left-hand column of Figure 4 (filled circles, continuous lines). For all three subjects, the regression line had a slope greater than 1.0, although the deviation from unity was statistically significant (t test, $p < 0.05$) only in the case of L.K. The regression line obtained for this subject also had an intercept (*i.e.*, the value of y at $x = 0$) whose value was significantly greater than zero (t test, $p < 0.05$); however, the intercepts obtained for the remaining two subjects did not deviate significantly from zero. For all subjects, the correlation coefficients were greater than 0.95 (see Figure 4).

The right-hand column of Figure 4 shows the ratios of the times spent in the two components (T_A/T_B) plotted against the ratios of the reinforcement frequencies in the two components (r_A/r_B) on double logarithmic coordinates (Figure 4, filled circles, continuous lines). In no case did the slope of the line of best fit deviate significantly from unity, nor did the values of the intercepts deviate significantly from zero. The correlation coefficients all exceeded 0.94 (see Figure 4).

b. Performance in the presence of punishment for responding in Component B. The results obtained from each subject during the last three sessions in which responding in Component B was punished on a VR 34 schedule are shown in Figure 3 (open symbols and broken lines); the values of the constants are shown in Table 2.

For each subject, the rate of responding in Component A (R_A) was an increasing negatively accelerated function of reinforcement frequency in Component A (r_A). The values of the reinforcement frequency corresponding to the half-maximal response rate were markedly reduced compared to their values during Phase II (no punishment). Indeed, for two of the three subjects (L.K. and M.S.) there was no significant difference between the value of this constant obtained during Phase II (punishment) and its value obtained during Phase I (no punishment). The values of the theoretical maximum response rate were not significantly altered by the presence of punishment in Component B. The values of p^2 for the hyperbolic function were 0.958 (B.B.), 0.928 (L.K.), and 0.768 (M.S.).

The rates of responding in Component B (R_B) were uniformly low for all three subjects, and were not systematically related to reinforcement frequency in Component A (r_A), (see Figure 3).

The ratios of the response rates in the two components (R_A/R_B) were plotted against the ratios of the reinforcement frequencies in the two components (r_A/r_B) using double logarithmic coordinates. The results obtained are shown in the left-hand column of Figure 4 (open circles, broken lines). For all three subjects, the slope of the regression line was significantly less than unity (t test, $p < 0.01$); indeed, only in the case of M.S. did the slope deviate significantly from zero (t test, $p < 0.05$). For all subjects, the value of the intercept was significantly greater than zero (t test, $p < 0.01$). The correlation coefficients for the linear functions were 0.55 (B.B.), 0.65 (L.K.), and 0.96 (M.S.).

The right-hand column of Figure 4 shows the ratios of times spent in the components (T_A/T_B) plotted against the ratios of the reinforcement frequencies in the two components (r_A/r_B) on double logarithmic coordinates (Figure 4: open circles, broken lines). In no case did the slope of the line of best fit deviate significantly from zero; however, in every case the value of the intercept was significantly greater than zero (t test, $p < 0.01$). The correlation coefficients were 0.70 (B.B.), 0.97 (L.K.), and 0.90 (M.S.).

DISCUSSION

In agreement with our previous observations (Bradshaw *et al.*, 1976, 1977, 1978), the present results show that the behavior of humans on VI schedules of monetary reinforcement conforms to Herrnstein's equation (Equation 1). In assessing the conformity of the data to this equation, and in estimating the values of the constants, we used the nonlinear regression technique of Wilkinson (1961) for direct fitting of the curvilinear function; a similar iterative procedure has been described by de Villiers (1977). This method was chosen in preference to a linear transformation method (*e.g.*, Lineweaver and Burk,

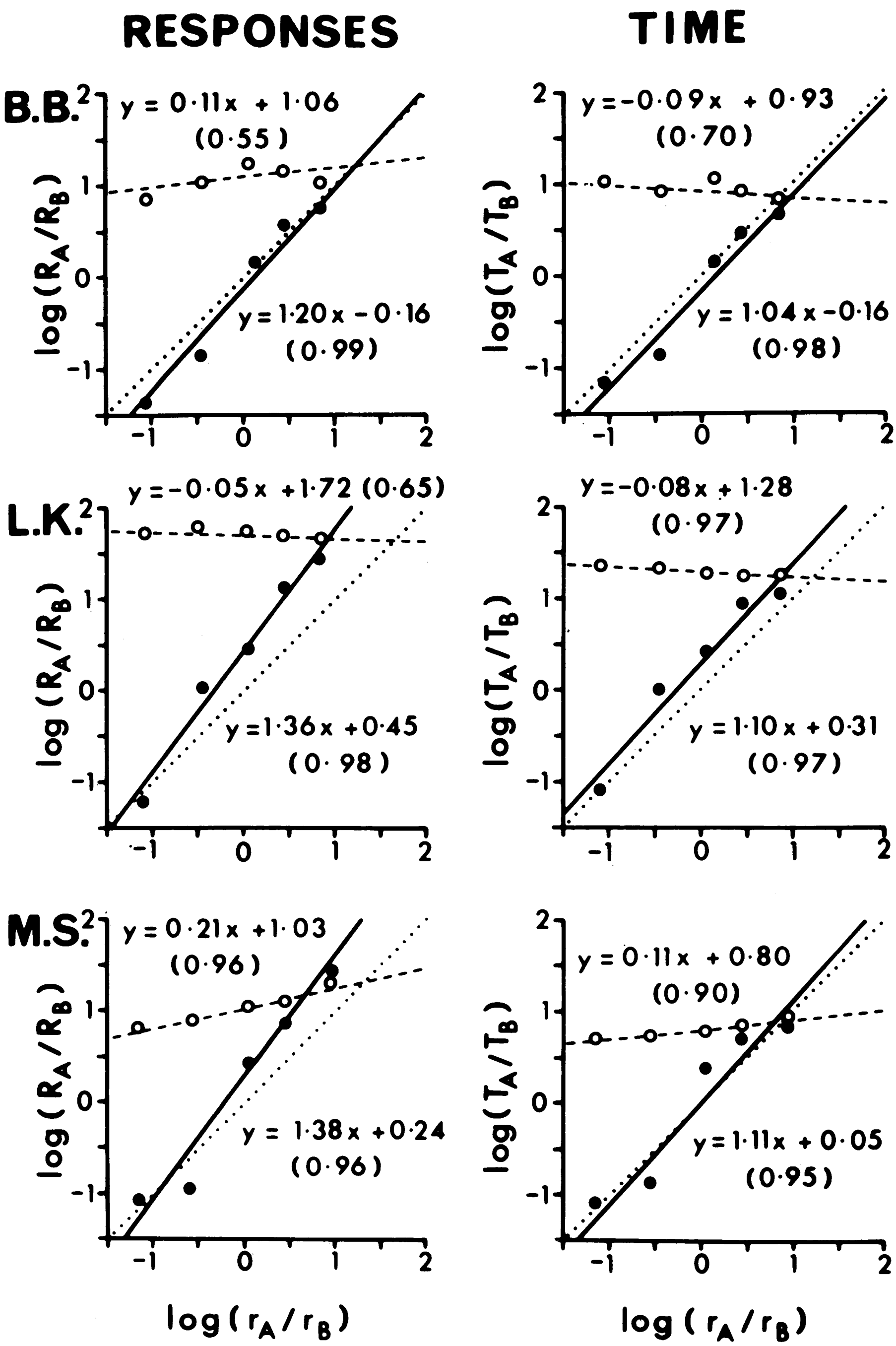

Fig. 4. Results obtained during Phase II. *Left-hand graphs:* ratios of response rates in the two components (R_A/R_B) plotted against ratios of reinforcement frequencies in the two component (r_A/r_B) using double logarithmic coordinates. Dotted lines show the locus of perfect matching. Filled circles show data obtained in the absence of punishment (continuous line is best-fit linear function obtained by least-squares method). Open circles show data obtained in the presence of variable-ratio 34 punishment for responding in Component B (broken line is best-fit linear function obtained by least-squares method). Equations for linear functions are shown in each graph; numbers in parentheses are correlation coefficients. *Right-hand graphs:* ratios of times spent in two components (T_A/T_B) plotted against ratios of reinforcement frequencies in two components (r_A/r_B) using double logarithmic coordinates. Conventions as in left-hand graphs.

1934; see also Bradshaw, 1977, and Cohen, 1973), since it has been shown that the nonlinear techniques are not subject to the statistical bias that is inevitably involved in linear transformation procedures (Parker and Waud, 1971; Wilkinson, 1961).

The data obtained during Phase I confirm our previous finding that punishment, in the form of response cost delivered on a VR schedule, suppresses performance in VI schedules, this suppression taking the form of a reduction in the value of the theoretical maximum response rate and an elevation in the value of reinforcement frequency corresponding to the half-maximal response rate (Bradshaw *et al.*, 1977).

During Phase II, in the absence of punishment, the absolute response rates in the two component schedules conformed closely to Equations 2 and 3. This is in agreement with previous observations of the behavior of pigeons (Catania, 1963; Davis and Hunter, 1976; Lobb and Davison, 1975) in concurrent VI schedules.

The left-hand column of Figure 4 shows the data obtained during Phase II (no punishment) in the form of ratios: the ratios of the response rates in the two components are plotted against the ratios of the reinforcement frequencies in the two components using double logarithmic coordinates. This method of display facilitates the recognition of two systematic deviations from perfect matching (*cf.* Equation 4b); a deviation of the intercept of the best-fit linear function from zero indicates a *bias* in favor of one of the component schedules, whereas a deviation of the slope of the linear function from unity indicates either *undermatching* (if the slope is less than 1.0) or *overmatching* (if the slope is greater than 1.0), (Baum, 1974). Only one subject in the present study (L.K.) showed a significant bias, this being in favor of Component A; the remaining subjects showed no consistent bias. All three subjects exhibited a certain degree of overmatching, although this overmatching achieved statistical significance in the case of only one subject (L.K.). When the logarithms of the ratios of the times spent in the two components were plotted against the logarithms of the ratios of the reinforcement frequencies in the two components (Figure 4, right-hand column), straight-line functions were obtained and there was no consistent bias and no consistent tendency toward overmatching. These observations accord well with numerous findings, obtained both with animals and with humans, that lend support to the Matching Law (for review see de Villiers, 1977).

By comparing Equation 1 with Equation 2, the following predictions may be derived concerning the effects of introducing the concurrent source of reinforcement (Component B) during Phase II (*cf.* Equations 5 and 6): (1) the curves derived from Phase I (no punishment) and Phase II (no punishment) should approach the same asymptotic response rate; (2) the reinforcement frequency (r_A) corresponding to the half-maximal response rate should be greater during Phase II (no punishment) than during Phase I (no punishment), this difference being equal to the reinforcement frequency for Component B (r_B). Findings consistent with these predictions were obtained in a previous study (Bradshaw *et al.*, 1976). In the present study, the first prediction was confirmed with all three subjects (see Table 2). With respect to the second prediction, all three subjects showed statistically significant increases in the value of r_A corresponding to the half-maximal response rate (see Table 2). In two subjects, the magnitude of this increase was close to the predicted increase of 70 reinforcements per hour (B.B.: 72.1 reinforcements per hour; M.S.: 83.0 reinforcements per hour). However, the increase observed with the remaining subject (L.K.) was only 26.8 reinforcements per hour. The reason for this discrepancy is not clear, although it is noteworthy that this subject also showed a significant bias toward Component A during Phase II (no punishment).

Comparing the results obtained during Phase II (punishment) and Phase II (no punishment), it is apparent that the superimposition of the VR 34 punishment schedule on the standard VI schedule in Component B had the following effects. (1) The response rates in Component B (R_B) were suppressed to uniformly low levels, comparable to those seen under the corresponding schedule in Phase I (punishment) (see Figure 3). (2) Concomitant with the decline in the response rates in Component B, response rate in Component A (R_A) increased; this increase was reflected in a reduction in the value of the reinforcement frequency corresponding to the half-maximal response rate (see Table 2): in other words, the punishment schedule abolished or attenuated the suppressant effect of r_B on R_A (see Figure 3). (3) These changes in the absolute response rates were reflected in a distortion of the matching relationship, which took the form of a bias in favor of Component A and a marked tendency toward undermatching (see Figure 4).

The effects of punishment, in the form of monetary loss, seen in this experiment are qualitatively comparable to the effects of electric shock on the behavior of pigeons and rats in concurrent schedules of food reinforcement. Azrin and Holz (1966), using pigeons, imposed a punishment contingency on one component of a two-component concurrent schedule. They observed a marked suppression of response rates in the punished component, and a concomitant increase in response rate in the other (unpunished) component. Deluty (1976), using rats, imposed a random-interval shock contingency on both components of a two-component concurrent schedule, maintaining the shock frequency constant in one component and varying it in the other. He observed that an increase in the shock frequency in one component reduced the response rate in that component and enhanced the response rate in the other component.

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